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I, Akio Shiga, a Patent Attorney, of 1-34-12 Kichijoji-Honcho, Musashino-shi, Tokyo, Japan, do solemnly and sincerely declare that I well understand the Japanese and English languages and that the attached English version is a full, true and faithful translation made by me

this 4th day of October, 2006

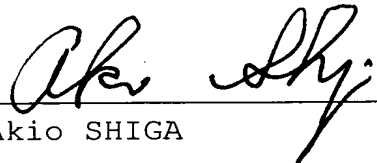
of the Japanese priority document of

Japanese Patent Application
No. 9-268973

entitled "LIQUID CRYSTAL DISPLAY"

In testimony thereof, I have herein set my name and seal

this 4th day of October, 2006



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[Title of the Invention] LIQUID CRYSTAL DISPLAY

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[Title of Invention] LIQUID CRYSTAL DISPLAY

[Claims]

5 [Claim 1] A vertically aligned type liquid crystal display comprising a liquid crystal layer disposed between a plurality of display electrodes and an opposing electrode and having liquid crystal molecules which are vertically aligned, the orientation of said liquid crystal molecules being controlled by an electric field; wherein

10 said opposing electrode opposing said display electrode has an orientation control window and a ratio of vertical to horizontal length of each of said display electrodes is equal to or more than 2.

15 [Claim 2] A vertically aligned type liquid crystal display comprising a liquid crystal layer disposed between a plurality of display electrodes and an opposing electrode and having liquid crystal molecules which are vertically aligned, the orientation of said liquid crystal molecules being controlled by an electric
20 field; wherein

said opposing electrode opposing said display electrode has an orientation control window, and each of said plurality of display electrodes is divided into two or more electrically connected portions so that a vertical to horizontal length ratio of each
25 portion is larger than that of each of said plurality of display electrodes.

[Claim 3] A vertically aligned type liquid crystal display

comprising a liquid crystal layer disposed between a plurality of display electrodes and an opposing electrode and having liquid crystal molecules which are vertically aligned, the orientation of said liquid crystal molecules being controlled by an electric field; wherein

said opposing electrode opposing said display electrode has an orientation control window, and each of said plurality of display electrodes is divided into two or more electrically connected portions, with a vertical to horizontal length ratio of each portion being equal to or more than 2.

[Detailed Description of Invention]

[0001]

[Field of the Invention]

The present invention relates to a liquid crystal display (LCD) which utilizes opto-electric anisotropy of liquid crystal and realizes display, and more particularly to a liquid crystal display which achieves an improved response speed and transmittance.

[0002]

[Conventional Art]

LCDs are compact, thin, and low power consumption devices and have been developed for practical use in the field of office automation (OA) and audio-visual (AV) equipment. In particular, active matrix type LCDs which utilize thin film transistors (TFTs) as switching elements are theoretically capable of static actuation at a duty ratio of 100% in a multiplexing manner, and have been used in large screen and high resolution type animation displays.

[0003]

TFTs are field effect transistors arranged in a matrix on a substrate and connected to individual display electrodes which form one side of pixel capacitors with a dielectric layer made of liquid crystal. In a TFT matrix, TFTs located on a same row are simultaneously turned on/off by a gate line, and each TFT of that row receives a pixel signal voltage from a drain line. A display voltage is accumulated in the pixel capacitors corresponding to the on-state TFTs and designated by rows and columns. The display electrodes and the TFTs are formed on the same substrate, while a common electrode acting as the other side of the pixel capacitors is formed on the entire surface of the second substrate opposite to the first substrate across the liquid crystal layer. That is, the display pixels are defined by partitioning the liquid crystal and the common electrode by display electrodes. The voltage accumulated in the pixel capacitors is held insulated by an off-state resistance of the TFTs for one field period or one frame period until the TFTs are turned on again. The liquid crystal is opto-electrically anisotropic, and its transmittance is controlled based on the voltage applied to respective pixel capacitors. The transmittance of each display pixel is independently controlled, so that individual pixels are observed bright or dark and recognized collectively as a display image by human eyes.

[0004]

Initial orientation of the liquid crystal is determined by an orientation film disposed at the interface between the liquid crystal and each substrate. For example, a twisted nematic (TN) type LCD uses the liquid crystal in nematic phase which has positive dielectric anisotropy and whose alignment vectors are twisted 90

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degrees between opposing substrates. Typically, a polarizing plate is provided on the outside of each substrate, and a polarizing axis of each polarizing plate coincides with the orientation of the liquid crystal located in the vicinity of the corresponding substrate in the TN system. When no voltage is applied, linearly polarized light passes through one polarizing plate, turns its direction in the liquid crystal layer along the twisted alignment of the liquid crystal, and exits from the other polarizing plate, resulting in a "white" display. When the voltage is then applied to the pixel capacitors, an electric field is created within the liquid crystal and the orientation of the liquid crystal is changed to be parallel to the direction of the applied electric field because of its dielectric anisotropy. This results in the collapse of twisted alignment and less frequent turns of the linearly polarized incoming light in the liquid crystal. Consequently, the amount of light ejecting from the other polarizing plate is reduced and the display gradually becomes black. This is known as a normally white mode which is widely applied in the field of TN cells, in which the display is white when no voltage is applied and changes to "black" upon application of the voltage.

[0005]

Figs. 6 and 7 show a unit pixel structure of a conventional liquid crystal display, wherein Fig. 6 is a plan view and Fig. 7 is a sectional view along line G-G of Fig. 6. A gate electrode (101) made of a metal, such as Cr, Ta, or Mo, is formed on a substrate (100), and a gate insulating film (102) made of, e.g., SiNx and/or SiO₂ is formed to cover the gate electrode (101). The gate insulating film (102) is covered with a p-Si (103) in which a doping stopper

9 41

(104) patterned into the shape of the gate electrode (101) and made of SiO₂ or the like is used to form a lightly doped region (LD) having a low concentration (N-) of impurities, such as P or As, and source and drain regions (S, D) having a high concentration (N+) of impurities located outside the LD region. A region located immediately below the doping stopper 104 is an intrinsic layer which includes substantially no impurities and acts as a channel region (CH). The p-Si (13) is covered with an interlayer insulating film (105) made of SiN_x or the like. A source electrode (106) and a drain electrode (107), both made of a material such as Al, Mo, or the like, are formed on the interlayer insulating film (105), each electrode being connected to the source region (S) and the drain region (D), respectively, via a contact hole formed in the interlayer insulating film (105). The entire surface of the thus formed TFT is covered with a planarization insulating film (108) made of SOG (spin on glass), BPSG (boro-phospho silicate glass), acrylic resin, or the like. A display electrode (109) made of a transparent conductive film such as ITO (indium tin oxide) is formed on the planarization insulating film (108) for actuating the liquid crystal, and is connected to the source electrode (106) via a contact hole formed in the planarization insulating film (108).

[0006]

An orientation film (120) formed by a high molecular film, such as polyimide, is disposed on the entire surface on the above elements and is applied a rubbing treatment so that an initial orientation of the liquid crystal is controlled. Meanwhile, a common electrode (131) made of ITO is formed on the entire surface

of another glass substrate (130) arranged opposite to the substrate (100) across a liquid crystal layer. The common electrode (131) is covered with an orientation film (133) made of polyimide or the like and is applied a rubbing treatment.

5 [0007]

As shown herein, a DAP (deformation of vertically aligned phase) type LCD uses a nematic phase liquid crystal (140) having negative dielectric anisotropy, and orientation films (120, 133) formed by a vertical orientation film. The DAP type LCD is one of the electrically controlled birefringence (ECB) type LCDs which use a difference of refractive indices of major and minor axes of a liquid crystal molecule, so-called a birefringence, to control transmittance. In the DAP type LCD, upon application of a voltage, an incoming light transmits one of two orthogonal polarization plates and enters the liquid crystal layer as a linearly polarized light, and is birefracted in the liquid crystal layer to become an elliptically polarized light. Then, retardation, which is a difference of phase velocity between ordinary and extraordinary ray components in the liquid crystal, is controlled according to an intensity of the electric field in the liquid crystal layer to allow the light to be emitted from the other polarization plate at a desired transmittance. In this case, the display is in a normally black mode, since the display is black when no voltage is applied and changes to white upon application of an appropriate voltage.

[0008]

[Problem to be solved by Invention]

As described above, the liquid crystal display displays an

image at an intended transmittance or color phase by applying a desired voltage to the liquid crystal sealed between a pair of substrates having predetermined electrodes formed thereon and by controlling a turning route or a birefringence of light in the liquid crystal layer. Specifically, the retardation is controlled by changing the alignment of the liquid crystal, to thereby adjust the light intensity of the transmitted light in the TN mode, while allowing the separation of color phases in the ECB mode by controlling a spectroscopic intensity depending on wavelength. Since the retardation depends on the angle between the major axis of the liquid crystal molecule and the orientation of the electric field, the retardation still changes relative to the viewer's observation angle, i.e., a viewing angle, even when such an angle is primarily controlled by the adjustment of the electric field intensity. As the viewing angle changes, the light intensity or the color phase of the transmitted light also changes, causing a so-called viewing angle dependency problem.

[0009]

Problems of decreased transmittance and slower response speed also remain.

[0010]

[Means for solving the problem]

SUMMARY OF THE INVENTION

According to one aspect of the present invention, there is provided a vertically aligned type liquid crystal display comprising a liquid crystal layer disposed between a plurality of display electrodes and an opposing electrode and having liquid crystal

molecules which are vertically aligned, the orientation of said liquid crystal molecules being controlled by an electric field, wherein said opposing electrode opposing said display electrode has an orientation control window and a ratio of vertical to horizontal length of each of said display electrodes is equal to or more than 2.

[0011]

According to another aspect of the present invention, there is provided a vertically aligned type liquid crystal display comprising a liquid crystal layer disposed between a plurality of display electrodes and an opposing electrode and having liquid crystal molecules which are vertically aligned, the orientation of said liquid crystal molecules being controlled by an electric field, wherein said opposing electrode opposing said display electrode has an orientation control window, and each of said plurality of display electrodes is divided into two or more electrically connected portions so that a vertical to horizontal length ratio of each portion is larger than that of each of said plurality of display electrodes.

[0012]

According to another aspect of the present invention, there is provided a vertically aligned type liquid crystal display comprising a liquid crystal layer disposed between a plurality of display electrodes and a common electrode and having liquid crystal molecules which are vertically aligned, the orientation of said liquid crystal molecules being controlled by an electric field, wherein said opposing electrode opposing said display electrode has an orientation control window, and each of said

plurality of display electrodes is divided into two or more electrically connected portions, with a vertical to horizontal length ratio of each portion being equal to or more than 2.

[0013]

5 With this structure, the influences in the edge portions of the display electrode can be reduced, and, consequently, the viewing angle characteristic and transmittance are improved and the average response time is reduced.

10 [0014]

[Preferred Embodiments]

Referring to Figs. 1 and 2, a unit pixel structure of a liquid crystal display according to the a preferred embodiment of the present invention is shown, wherein Fig. 1 is a plan view and Fig.
15 2 is a sectional view taken along line A-A of Fig. 1. A gate electrode (11) made of a metal, such as Cr, Ta, or Mo, is formed on a substrate (10), and a gate insulating film (12) made of, e.g., SiNx and/or SiO₂ is formed to cover the gate electrode (11). The gate insulating film (12) is covered with p-Si (13) in which a doping stopper (14)
20 such as SiO₂ which is patterned into a shape of the gate electrode (11) is used to form a lightly doped region (LD) having a low concentration (N-) of impurities, such as P or As, and source and drain regions (S, D) having a high concentration (N+) of impurities located outside the LD region. A region located immediately below
25 the doping stopper 14 is an intrinsic layer which includes substantially no impurities and acts as a channel region (CH). The p-Si (13) is covered with an interlayer insulating film (15) made of SiNx or the like. A source electrode (16) and a drain

electrode (17), both made of Al, Mo, or the like, are formed on the interlayer insulating film (15), each electrode being connected to the source region (S) and the drain region (D), respectively, via a contact hole formed in the interlayer insulating film (15).

5 The entire surface of the thus formed TFT is covered with a planarization insulating film (18) made of SOG (spin on glass), BPSG (boro-ph-ospho silicate glass), acrylic resin, or the like. A display electrode (19) made of a transparent conductive film such as ITO (indium tin oxide) is formed on the planarization
10 insulating film (18) for actuating the liquid crystal, and is connected to the source electrode (16) via a contact hole formed in the planarization insulating film (18).

[0015]

An orientation film (20) formed by a macro molecular film,
15 such as polyimide, is formed on the entire surface of the above elements, while a common electrode (31) made of ITO is formed on the entire surface of another glass substrate (30) arranged opposite to the substrate (10) across a liquid crystal layer. The common electrode (31) is covered with an orientation film (33) made of
20 polyimide or the like. In the present invention, the orientation films (20), (33) and the liquid crystal (40) are selected so that liquid crystal molecules (41) are aligned vertically.

[0016]

In addition, an orientation control window (50) is formed
25 in the common electrode (31) facing the display electrode (19) and in the form of two upper and lower Y-shaped slits connected symmetrically to each other. Since the electric field applied to the liquid crystal molecules (41) located below the orientation

control window is not sufficiently strong to tilt those molecules (41), they have vertical alignment. Around these molecules (41), however, the electric field is created as indicated by a dotted line in Fig. 2, which controls the liquid crystal molecules (41) to direct their major axes perpendicular to the applied electric field. This is also true at the edge sections of the display electrode (19) and the major axes of the liquid crystal molecules (41) are oriented perpendicularly to the electric field. The tilt of these molecules is propagated to other molecules located in the interior of the layer because of continuity of the liquid crystal. Thus, the liquid crystal molecules are oriented in substantially the same direction in the center part of the display electrode (19), but the orientation is uneven in the vicinity of the edge sections, as shown by an arrow in Fig. 1. It has been found that better viewing angle characteristic and transmittance are achieved when the orientation is uniform and worse viewing angle characteristic and transmittance are observed when the orientation is not uniform.

[0017]

Because of this, in the present invention, an aspect ratio, i.e., a vertical to horizontal length ratio V/H of the display electrode (19) facing the orientation control window (50) is set to at least 2. As such, it is possible to enlarge an area where the liquid crystal molecules are oriented in the same direction, while decreasing the share of an unevenly oriented area. This allows the viewing angle characteristic, the transmittance, and even the response speed to be improved.

[0018]

Fig. 3A shows the experimental results, and plots an aspect

ratio of the display electrode (19) relative to its transmittance and average response time $((\tau_{on} + \tau_{off})/2)$, respectively. As shown in the graph of Fig. 3A, the transmittance is low until the aspect ratio reaches 2, and then increases to a preferable value and remains on that value at the aspect ratio of greater than 2. As shown in the graph of Fig. 3B, the average response time is slow until the aspect ratio reaches 2, and then accelerates and generally remains unchanged after that. Namely, with the aspect ratio of the display electrode (19) equaling to 2 or more, a higher transmittance and a reduced average response time are achieved.

[0019]

Referring next to Figs. 4 and 5, another embodiment of the present invention will be described.

Fig. 4 is a plan view showing a unit pixel structure of the liquid crystal display and Fig. 5 is a sectional view taken along line A-A of Fig. 4. It is to be noted that, for the sake of clarity the TFT structure is shown in a simple form in Fig. 5, but it is of the same structure as that shown in Fig. 2.

In this embodiment, the horizontal length of the display electrode (19) corresponding to the unit pixel is longer than the vertical length. Thus, slits (19d) and (19e) are formed vertically in the display electrode (19), dividing the display electrode (19) into three pixel display electrodes (19a), (19b), and (19c) to set the aspect ratio V/H of each pixel display electrode to 2 or more. It is to be noted, however, that these pixel display electrodes (19a), (19b), and (19c) are partly connected to each other under the slits (19d) and (19e), because one display electrode corresponds to one pixel.

[0020]

Orientation control windows (32a), (32b), and (32c) are formed in the common electrode (31) on the opposing side, each window corresponding to each pixel display electrode (19a), (19b), and
5 (19c). In each pixel display electrode (19a), (19b), or (19c), the liquid crystal molecules are oriented in reverse about each orientation control window. This increases a uniform orientation area of the liquid crystal molecules, while decreasing an abnormal orientation area at the edge sections of the display electrode.
10 Thus, the viewing angle characteristic, transmittance, and response time are also improved, as in the above embodiment.

[0021]

[Advantages]

As is clear from the above description, because the aspect
15 ratio of the display electrode or a divided display electrode in which the display electrode is divided is set to a predetermined value or greater, the influences of the edge section of the display electrode can be reduced, and, consequently, the viewing angle characteristic and the transmittance can be improved and the average
20 response time can be shortened.

[Brief Description of the Drawings]

[Fig. 1] A plan view showing a unit pixel of a liquid crystal display according to a preferred embodiment of the present invention.

[Fig. 2] A sectional view taken along line A-A of Fig. 1.

25 [Fig. 3] Graphs plotting an aspect ratio of the liquid crystal display as a function of a transmittance and an average response time, respectively, according to the present invention.

[Fig. 4] A plan view showing a unit pixel of the liquid crystal

display according to another embodiment of the present invention.

[Fig. 5] A sectional view taken along line A-A of Fig. 4.

[Fig. 6] A plan view showing a unit pixel of a conventional liquid crystal display.

5 [Fig. 7] A sectional view taken along line G-G of Fig. 7.

[Explanation of reference numerals]

10 SUBSTRATE

11 GATE ELECTRODE

10 12 GATE INSULATING FILM

13 p-Si

14 DOPING STOPPER

15 INTERLAYER INSULATING FILM

16 SOURCE ELECTRODE

15 17 DRAIN ELECTRODE

19 DISPLAY ELECTRODE

19a, 19b, 19c PIXEL DISPLAY ELECTRODE

20, 33 ORIENTATION FILM

30 GLASS SUBSTRATE

20 31 COMMON ELECTRODE

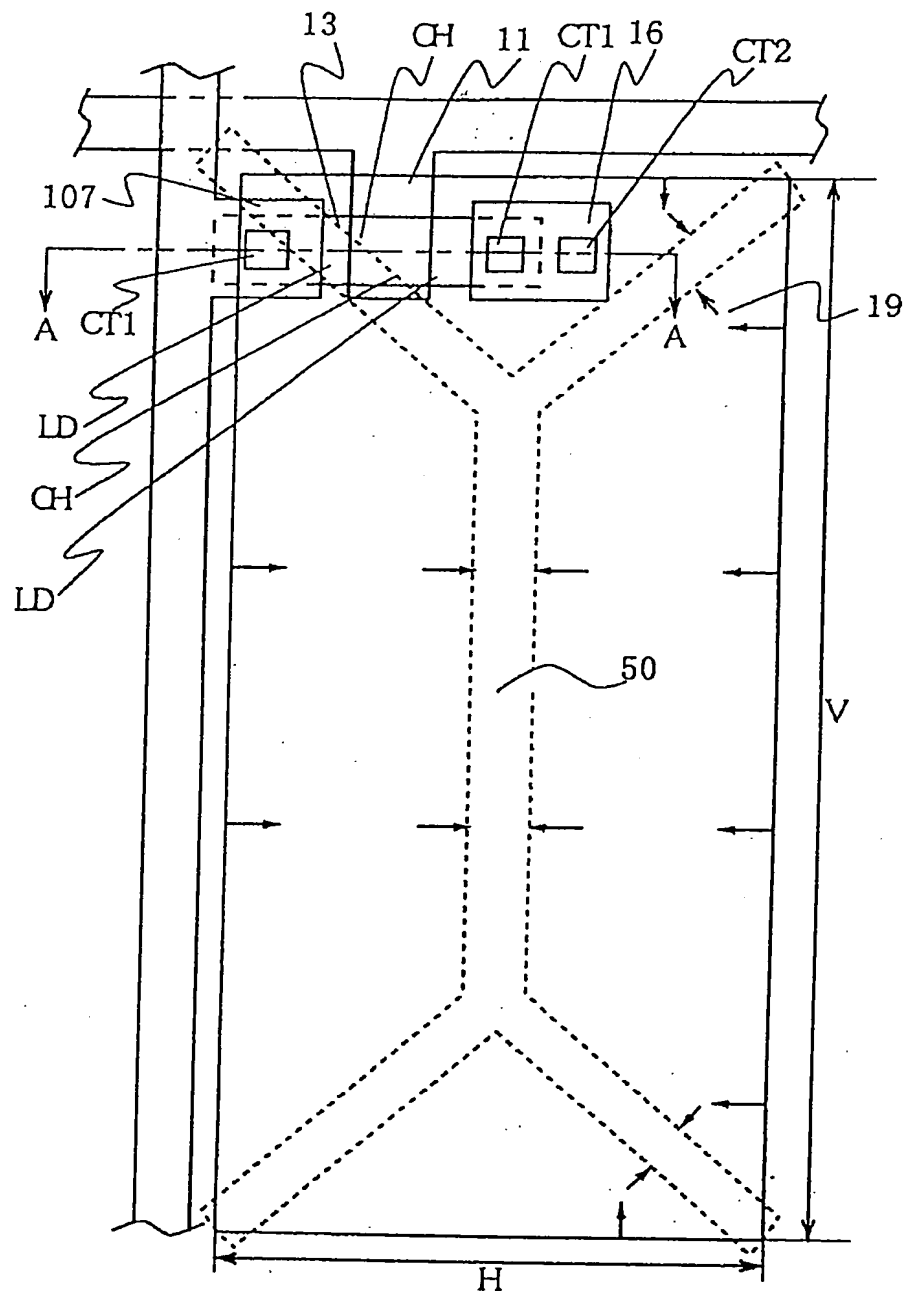
32a, 32b, 32c, 50 ORIENTATION CONTROL WINDOW

40 LIQUID CRYSTAL

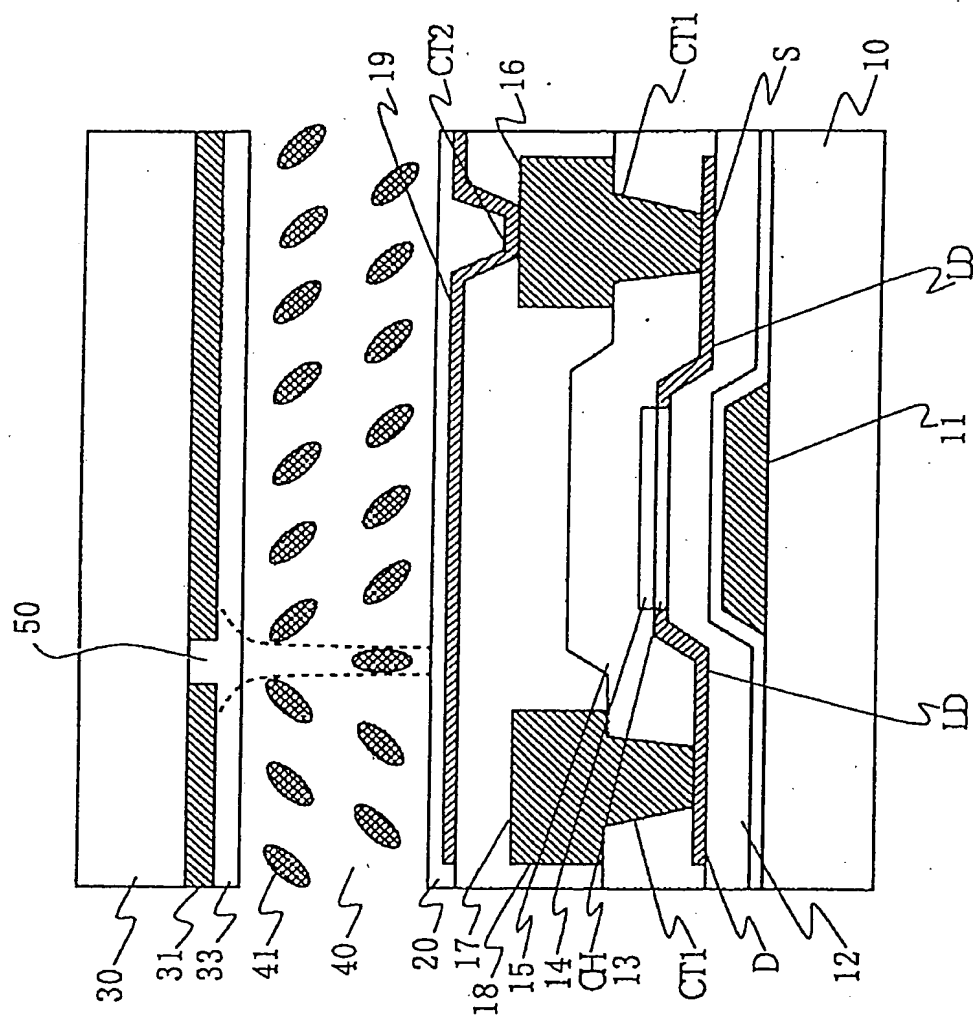
41 LIQUID CRYSTAL MOLECULE

[Name of Document] Drawings

[Fig. 1]

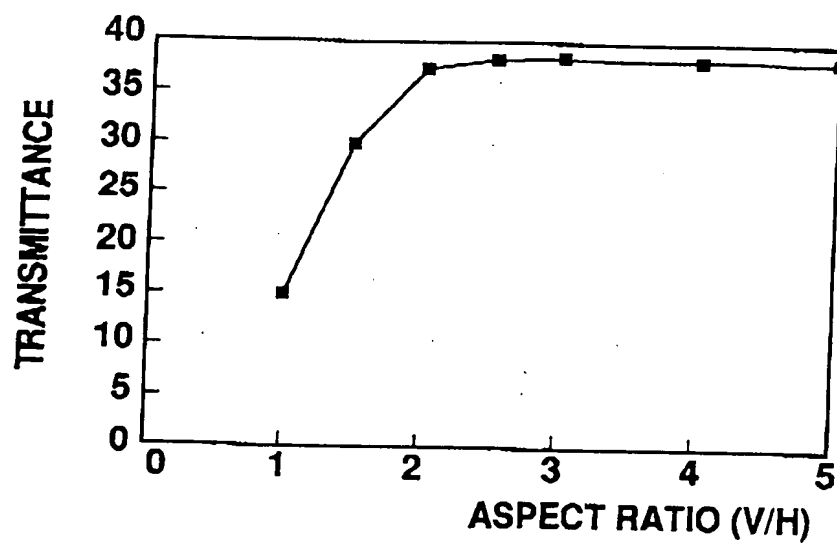


[Fig. 2]

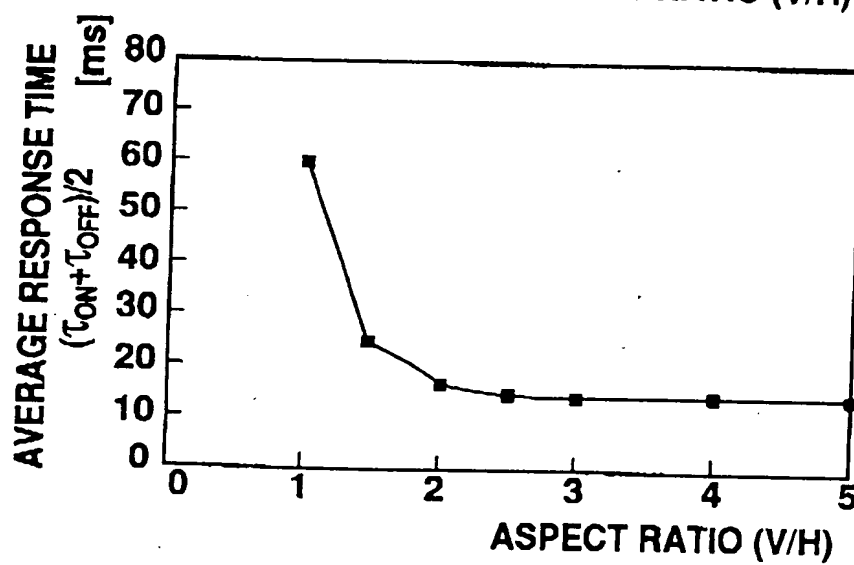


[Fig. 3]

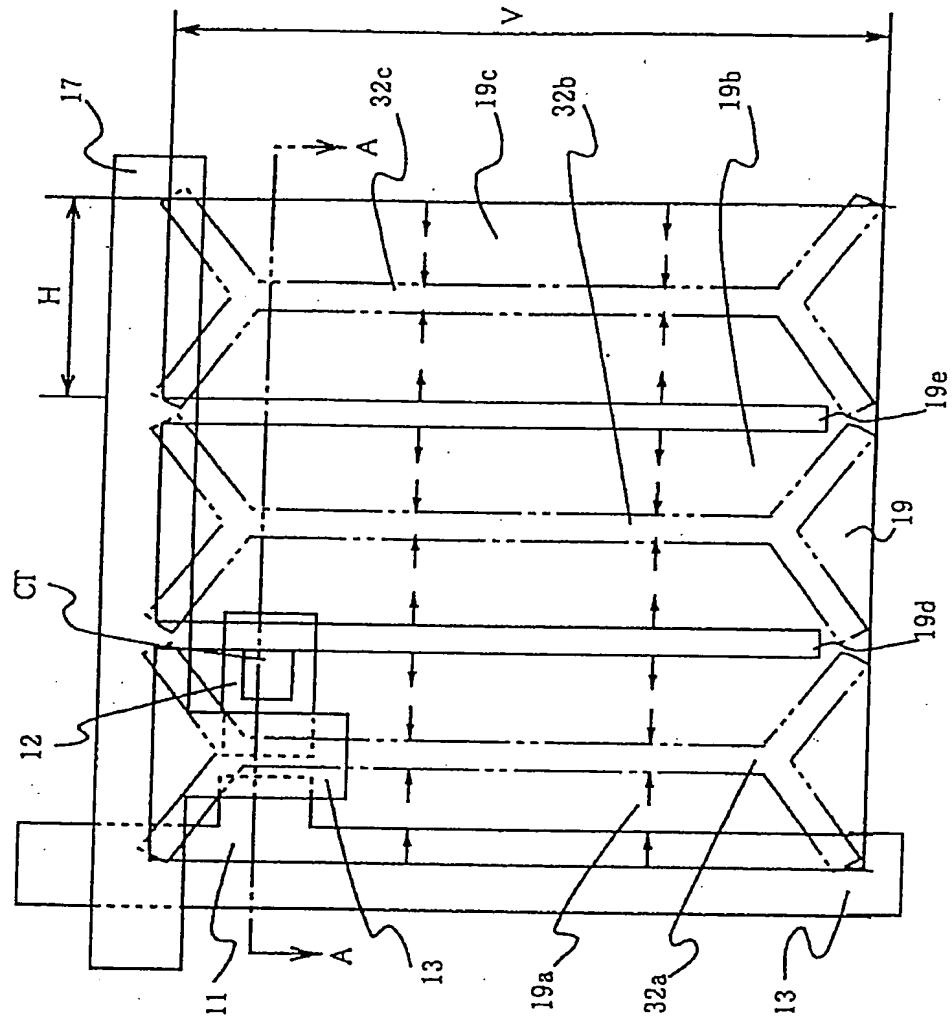
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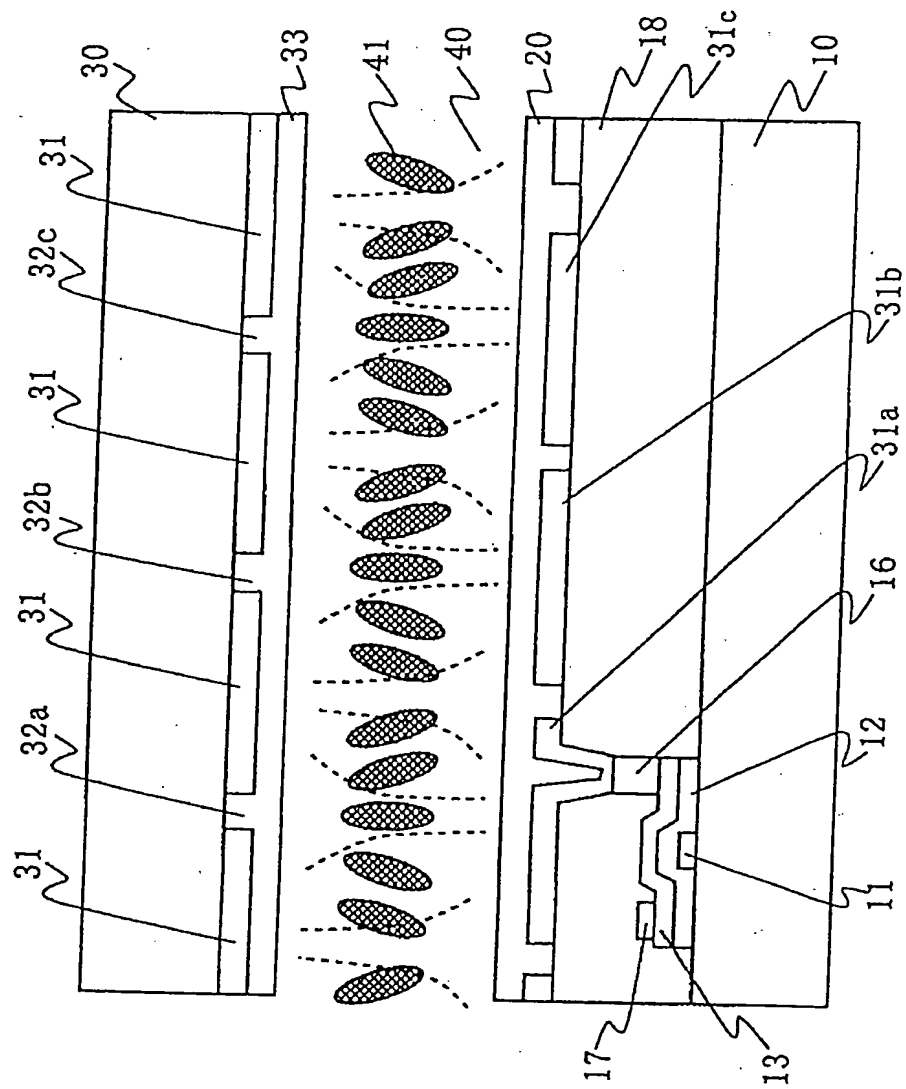
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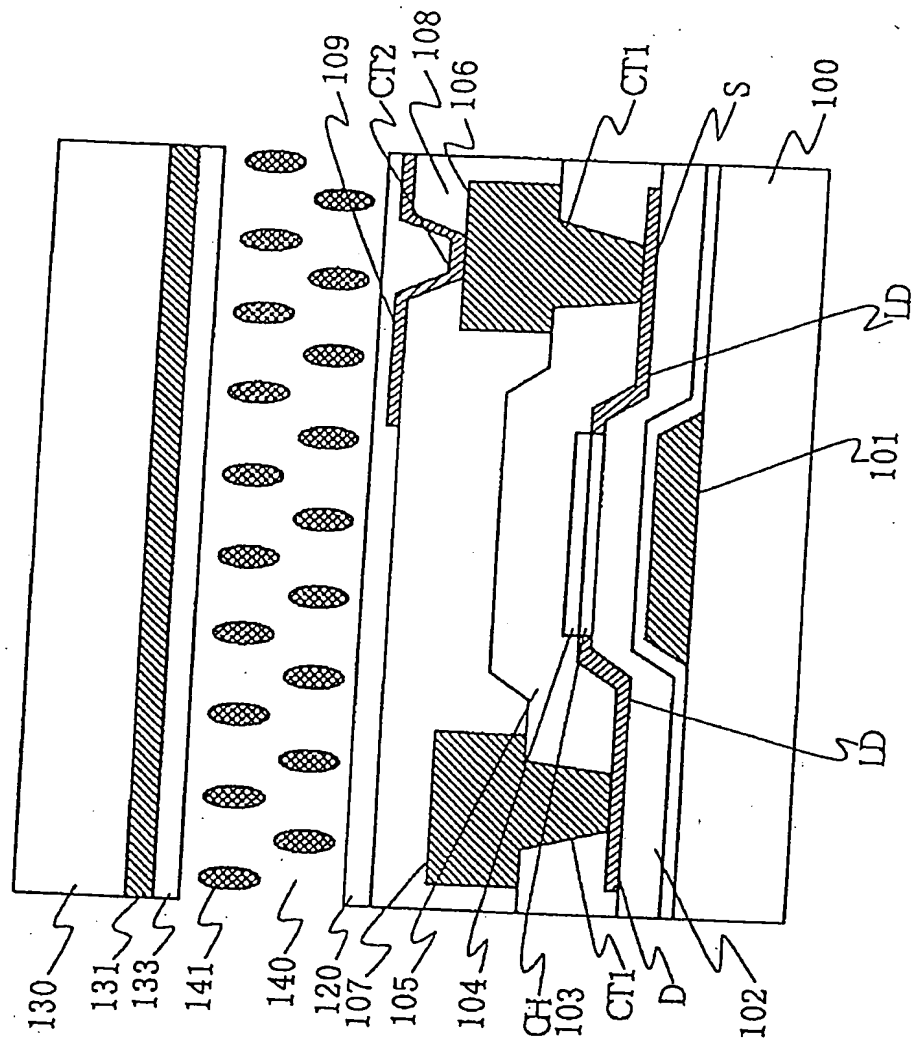
[Fig. 4]



[Fig. 5]



[Fig. 7]



[Name of Document] Abstract of the disclosure

[Summary]

[Problem] To reduce influences of edge sections of display electrode to improve viewing angle characteristic and transmittance and shorten average response time.

[Structure] A vertically aligned type liquid crystal display includes a liquid crystal layer (40) disposed between a display electrode (19) and an opposing electrode (30) and having vertically aligned liquid crystal molecules (41), the orientation of the liquid crystal molecules (41) being controlled by electric field. An orientation control window is formed in the common electrode located opposite to the display electrode and an aspect ratio of the display electrode (19) is set to at least 2. Alternatively, the display electrode is partitioned into at least two divided display electrodes (19a), (19b), and (19c). An orientation control window is formed in the common electrode so as to correspond to each divided display electrode and an aspect ratio of each divided display electrode is set to at least 2.

[Selected Drawing] Fig. 1